Saskatchewan
Agriculture
and Food

ADF

AGRICULTURE DEVELOPMENT FUND

FINAL REPORT

20050725

STRATEGIES FOR IMPROVING THE EFFICIENCY AND CROP SAFETY OF STARTER FERTILIZER

Funded by: The Agriculture Development Fund

March 2007

Prepared by: University of Saskatchewan

2007-04628/

Agriculture Development Fund Project no. 20050725

Strategies for Improving the Efficiency and Crop Safety of Starter Fertilizer Phosphorus and Potassium

Final Report

January 2007

For: Agriculture Development Fund, Agrium, Potash and Phosphate Institute

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INTRODUCTION

Seed-row placed or "starter" phosphorus (P) fertilizer is an effective means for applying phosphorus because of the low mobility of P in prairie soils and the need for annual crops to access P early on in the growth cycle. Early season crop shoot yield and P concentrations were increased with increasing rates of seed-placed P regardless of soil test P (Lauzon and Miller, 1997). However, the germination and emergence of crop seeds may be negatively affected by seed-placed phosphate fertilizer, as some crop seeds are especially sensitive to fertilizer salts. Guidelines are needed for maximum safe rates of fertilizer P with seed. New P fertilizer forms are being developed that slow the release of P to soil solution via a coating on the granule. The new P fertilizer form, termed controlled release phosphorus (CRP), may permit higher rates of P fertilizer to be safely seed placed. Controlled-release P fertilizer has a potential advantage to ensure safer use of P for crops in the seed-row as the plant available P is released at a slow rate and the salt effect on germination is diminished. This can allow plants to use it more effectively at high rates than the conventional monoammonium phosphate (MAP) fertilizer. As a result, a potential for improvement of fertilizer P efficiency and crop production may exist (Pauly et. al., 2002). It may be also beneficial when side-row fertilizer placement is considered. As potassium fertilizer is also becoming more commonly used on the prairies as a starter nutrient along with P, examining the impact of combined use of starter P and K in the seed-row on crop emergence, yield and uptake is useful for developing guidelines for attaining optimum benefit from seed-row placed P and K fertilizer.

The objectives of the series of studies covered in this report were (1) to determine how seed-row placed P at various rates influences germination, emergence, early plant growth (yield and P uptake) for eleven crops commonly planted in western Canada, (2) to compare how a new concept controlled release (CRP) P fertilizer product by Agrium Inc. compares to conventional MAP in performance, and (3) to examine the effect of KCl added at 20 kg K_2O ha^{-1} (typical starter seed-row placed K rate in prairies) together with the P fertilizer sources.

MATERIALS AND METHODS

Experiment Design

The experiments started in 2004 and were completed by the end of 2006. The first experiment set up in 2004 was a growth chamber study that investigated the effects of five different rates (0, 10, 20, 30, and 40 kg P_2O_5 ha^{-1}) of seed-row placed conventional monoammonium phosphate fertilizer (MAP) on seedling emergence (over two weeks) and plant yield and P uptake over the first month of growth for ten crops (excluding oat). The results of this first study are covered in ADF final report 2003 O545 May 2005. The experiments in late 2005 and 2006 covered in this report were set up to compare controlled-release monoammonium phosphate fertilizer (Agrium Inc. CRP) to conventional MAP fertilizer when placed in the seed-row at different rates alone and with K, for its effect on emergence, plant yield and P uptake. The crops that were used in the study are described in Table 1. In this study, five crops: canola, mustard, yellow pea, alfalfa and flax were chosen and assessed first with seven different rates of P utilized (0, 10, 20, 30, 40, 60, and 80 kg P_2O_5 ha^{-1}). Another six crops were then evaluated (wheat, canary, oat, chickpea, pinto bean, bromegrass) along with the first five crops at eight different rates (0, 10, 20, 30, 40, 60, 80, and 100 kg P_2O_5 ha^{-1}). The two P fertilizer products were evaluated at these rates, with and without 20 kg K_2O ha^{-1} starter K. Seven rates of K alone (0, 10, 20, 30, 40, 60, 80 kg K_2O ha^{-1}) were also evaluated.

Two types of experiments were set up: one in the lab in flats to determine the effect on seedling emergence and the other in the growth chamber in large trays to allow sufficient root volume to grow the plants for one month. In the lab eleven crops were involved. For the growth chamber study, wheat, canola, pea and flax were used for evaluating the effect of P fertilizer rate and form with and without K on plant yield and P uptake. An attempt was made to measure P supply rate in the growth chamber trays using PRS probe but due to the immobility of the P and subsequent lack of significant movement away from the band, and subsequent high variability, no significant differences

could be detected among treatments and it was decided to rely on the plant uptake as a measure of P availability.

Soil, Fertilizer and Crop Seeds

The soil used in this study was collected from the 0-15 cm depth in the spring of 2004, 2005, and 2006 from a field in the Brown soil zone in south-central Saskatchewan near Mawer, where the soil is mapped as Haverhill association of loamy texture. The field had never received phosphorus fertilizer and had been in alfalfa for the last 10 years. After collection, the soil was mixed thoroughly in a soil mixer and stored in field-moist condition before use. For measuring basic soil properties, a sample was collected from the mixed soil, and then air-dried, crushed, and passed through a 2-mm sieve and stored at room temperature. Texture was estimated by hand. Electrical conductivity (EC) and pH were measured using 1:1 soil:water suspension. Organic C was measured using Leco carbon analyzer. Available P and K were extracted by modified Kelowna method (Qian at al., 1994). Selected soil characteristics are summarized in Table 2. The fertilizer phosphorus sources used were 1) conventional commercial fertilizer grade monoammonium phosphate MAP (12-51-0) and 2) controlled release P fertilizer CRP, a pilot product of monoammonium phosphate produced with a polymer coating to slow release of P. The potassium source used was fertilizer grade potash (KCl) 0-0-60.

Table 1. The crops utilized in the study and seeding rates used*

Crop	Variety	Seed Rate kg ha^{-1}
(1) With better established responses:		
Wheat	Prodigy	112
Argentine Canola OP non HT	Sprint	12
Yellow pea	Carneval	410
Flax	CDC Vimy	35
(2) With limited information:		
Canary seed	Common Itchless	40
Oriental Mustard	Cutlass	11
Kabuli Chickpea	Xena	1450
Pinto Bean	Pintium	940
Alfalfa	Beaver	10
Bromegrass	Knowles	40
Oat	Triple Crown	134

*Certain crops were seeded at higher rates than would normally be used in the field so as to ensure sufficient seedlings were present in each treatment.

Table 2. Some characteristics of the soil for seed-placed fertilizer evaluation.

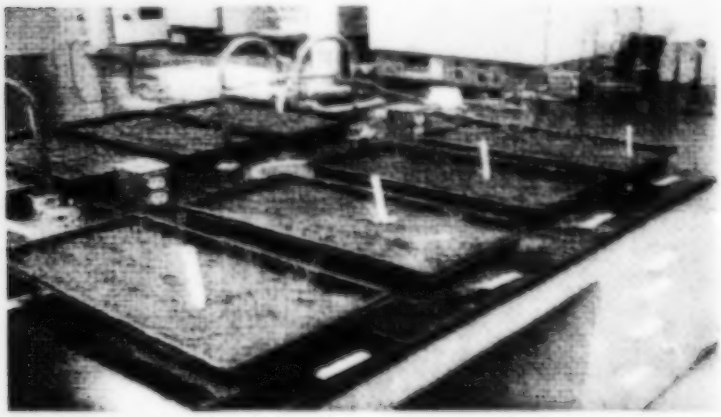
Soil	pH	EC mS cm^{-1}	Texture	Organic C g kg^{-1}	Available P* kg ha^{-1}	Extractable K* kg ha^{-1}
Haverhill	7.7	1.04	loamy	19.9	18.0	1178

*measured by modified Kelowna method

Laboratory Study

Mixed soil was placed into flats approximately 60 cm long, 40 cm wide and 5 cm deep. The soil added to the flats was field-moist and further water was added as needed to bring the soil to field

capacity. Soil was kept moist consistently to about 80% field capacity during a period of 2 weeks by watering every other day. All the treatments for different fertilizer rates were replicated four times. Seedbeds of approximately 20 cm in length and 10 cm in width were created in the flats to provide a replicate seedbed for each crop and P fertilizer rate. Seed rows or furrows were made by simulating a low-disturbance knife type opener with ~ 15% seedbed utilization and on-row packing. Fertilizer pellets were first placed in the furrows followed by the crop seeds. Lights in the lab were kept on day and night. Emergence counts started from 5 days after planting until about two weeks, when no additional emergence, in general, was observed.



Flats of Soil Used for Emergence Counts in the Laboratory.

Growth Chamber Study

Mixed soil was placed into deep trays approximately one meter long, 15 cm wide and 15 cm deep. The soil added to the trays was field-moist and further water was added to bring the soil to field capacity. All the different rates of fertilizer treatments were made with four replications of each treatment. A seeding tool was used as described for the laboratory study that simulates a low-disturbance knife or hoe type opener with a seedbed utilization of ~ 15% (1.5 inch spread and 10 inch row spacing) and on-row packing. This tool was used to place the seed at the appropriate depth along with the fertilizer together in the seed row. Rows of approximately 0.5 meters in length were created in the flats to provide a replicate for each crop and fertilizer rate of P or K.

A period of two weeks following seeding and fertilizing was used for assessing seed emergence and four weeks for harvesting the plants to assess plant growth variables including yield and P uptake. Emergence counts were made once every 5 days after planting. The trays of soil were kept near field capacity by surface watering twice per day and thorough watering once every two days. High airflow in the growth chambers was used to simulate drying in between watering as would occur in the field for the yield and P uptake studies while no air-flow was used in the laboratory studies. As such, the emergence data reported on here for 2005 and 2006 was obtained under continuous conditions of good moisture. Growth chamber conditions were 15°C temperature with 18 hour day length and 6 hour night period. After 4 weeks, the above ground portions of the plants in the trays were harvested. The plants were then dried, and weighed to determine dry matter yield. Ground plant material was digested using sulfuric acid-peroxide at 360°C and the phosphate in the digest determined using automated colorimetry.

Trays of Soil Used for Biomass Yield and P Uptake Measurements in Growth Chamber.

RESULTS & DISCUSSION

Effect of P Fertilizer Rate on Emergence Counts

Results from the initial 2004 growth chamber study with conventional MAP only were covered in a previous final report and are used here as a reference because the highest rate was only set at 40 kg P_2O_5 ha^{-1} and soil moisture level in the initial study was more variable compared to the laboratory studies set up in late 2005 and 2006. The results and discussion here emphasize the results from the late 2005 and 2006 lab studies.

Yellow pea, flax, and mustard are the most sensitive to seed-row P placement as a negative impact over the range of rates examined was observed at rates above 20 kg P_2O_5 ha^{-1} (Tables 4 and 5). When combining 20 kg K_2O with P in the seed row, a significant decrease in emergence for yellow pea even occurred at the rate of 20 kg P_2O_5 ha^{-1} (Table 5). Canola, canary seed, bromegrass, alfalfa, pinto bean and chickpea were less sensitive to seed-row P placement, with a negative impact occurring mainly at rates between 30 – 40 kg P_2O_5 ha^{-1} and above (Tables 3, 4 and 5). The least sensitive crops are wheat and oat. Negative impact for these crops was occurring at the rates of 40-60 kg P_2O_5 ha^{-1} or above. For crops like wheat and oat, the combination of 20 kg K_2O ha^{-1} with P had little influence on germination and emergence. This was also true for bromegrass, and even flax. However, other crops like canary seed and pea showed some further injury when 20 kg K_2O was added along with the P. A slight trend towards reduced emergence from addition of the 20 kg K_2O was also observed for canola and mustard.

Table 3. Percentage of seeds planted that emerged over 2 weeks as affected by different rates of conventional MAP fertilizer with or without 20 kg K_2O ha^{-1} potash for wheat, canola, and canary seed.

Fert. rate	Wheat			Canola				Canary		
	P only		With K	P only			With K	P only		With K
kg P_2O_5 ha^{-1}	2004*	2006	2006	2004*	2005	2006	2006	2004*	2006	2006
0	98a	93a	91a	96a	96a	95a	89a	93a	83a	63a
10	96a	95a	91a	96a	98a	98a	86a	83a	79a	61a
20	94a	91a	89ab	88a	90ab	95a	82a	86ab	79a	69a
30	96a	89ab	86ab	94a	83b	91a	80a	82b	73ab	58ab
40	94a	91a	86ab	94a	69c	73b	75a	88ab	68bc	56ab
60		80b	82b		48d	48c	59b		59c	46b
80		64c	68c		48d	43c	45bc		53cd	33c
100		52d	59d			36c	43c		38d	30c

Means in columns followed by a different letter are significantly different at $p < 0.05$.
*The 2004 experiment was conducted in the growth chamber and other years were conducted in the laboratory.

Table 4. Percentage of seeds planted that emerged over 2 weeks as affected by different rates of conventional MAP fertilizer with or without 20 kg K_2O ha^{-1} potash for bromegrass, mustard, and yellow pea.

Fert. rate	Bromegrass			Mustard				Yellow pea		
	P only		With K	P only			With K	P only		With K
kg P_2O_5 ha^{-1}	2004*	2006	2006	2004*	2005	2006	2006	2004*	2005	2006
0	50a	69a	61a	62a	73a	70a	64ab	91a	97a	75a
10	47ab	62a	59ab	51a	70a	63ab	66a	94a	76ab	68ab
20	44ab	59ab	55ab	52a	65a	66ab	55abc	63b	75ab	54bc
30	48a	58ab	57ab	35b	43b	55b	50bc	53b	72b	39cd
40	26ab	57ab	57ab	33b	33b	41c	46cd	50b	56b	25de
60		50b	52b		12c	38cd	32de		28c	18e
80		26c	25c		7c	34cd	29e		19c	11e
100		23c	17c			27d	18e			11e

Means in columns followed by a different letter are significantly different at $p < 0.05$.
*The 2004 experiment was conducted in the growth chamber and other years were conducted in the laboratory.

Table 5. Percentage of seeds planted that emerged over 2 weeks as affected by different rates of conventional MAP fertilizer with or without 20 kg K_2O ha^{-1} potash for pinto bean, alfalfa, and flax.

Fert. rate	Pinto bean			Alfalfa			Flax			
	P only	With K		P only		With K	P only			With K
kg P_2O_5 ha^{-1}	2004*	2006	2004*	2005	2006	2006	2004*	2005	2006	2006
0	81a	89a	74a	71a	72a	72a	46a	69a	67ab	65a
10	75a	86a	78a	70a	69a	74a	45a	63ab	69a	63ab
20	78a	82ab	61b	66a	67a	69ab	47b	64ab	65ab	63ab
30	88a	82ab	53b	54b	71a	64abc	51b	56b	54bc	54b
40	75a	79ab	51b	45b	46b	57bc	43a	45b	42cd	43c
60		71b		26c	44b	53c		26c	33de	35cd
80		46c		11d	39bc	24d		11c	22e	31de
100		32d			29c	18d			21e	22e

Means in columns followed by a different letter are significantly different at $p < 0.05$.
*The 2004 experiment was conducted in the growth chamber and other years were conducted in the laboratory.

Table 6. Percentage of seeds planted that emerged over 2 weeks as affected by different rates of conventional MAP fertilizer with or without 20 kg K_2O ha^{-1} potash for chickpea and oat.

Fert. rate	Chickpea		Oat	
	P only	With K	P only	With K
kg P_2O_5 ha^{-1}	2004*	2006	2006	2006
0	63a	86a	92a	89a
10	59a	82a	89a	86ab
20	59a	86a	89a	86ab
30	50a	75a	86a	83ab
40	56a	71a	81a	81ab
60		68a	78a	75b
80		36b	61b	58c
100		46b	58b	50c

Means in columns followed by a different letter are significantly different at $p < 0.05$.
*The 2004 experiment was conducted in the growth chamber and other years were conducted in the laboratory.

The high sensitivity of yellow peas and flax to seed placed P has been documented previously. In comparison to conventional MAP (Tables 3,4,5,and 6), the controlled-released CRP fertilizer product showed no negative impact on emergence even at rates up to 80-100 kg P_2O_5 ha^{-1} (Tables 7, 8 and 9) with the exception of yellow peas where a trend towards decrease in the emergence counts was noted at the rate of 60 kg P_2O_5 ha^{-1} and above (Table 8) and for bromegrass where decrease in the emergence counts was observed at the 80 kg P_2O_5 ha^{-1} together with 20 kg K_2O ha^{-1} (Table 8). Again, as for conventional MAP, the additional of 20 kg K_2O ha^{-1} seem to have the greatest effect on reducing germination for pea, canary seed, canola and mustard.

Table 7. Percentage of seeds planted that emerged over 2 weeks as affected by different rates of controlled released phosphorus (CRP) fertilizer with or without 20 kg K_2O ha^{-1} potash for wheat, canola, canary, and flax.

Fert. rate	Wheat		Canola			Canary		Flax		
	P only	With K	P only		With K	P only	With K	P only		With K
kg P_2O_5 ha^{-1}	2006	2006	2005	2006	2006	2006	2006	2005	2006	2006
0	93a	91a	90a	95a	89a	81a	63a	60a	67a	65a
10	93a	91a		95a	86a	80a	63a		68a	69a
20	95a	93a	92a	93a	80a	83a	63a	56a	69a	65a
30	93a	91a		86a	82a	78a	61a		72a	64a
40	89a	93a	96a	91a	80a	75a	56a	60a	69a	68a
60	89a	91a	92a	86a	80a	73a	63a	60a	71a	64a
80	91a	91a	94a	91a	80a	75a	58a	59a	65a	63a
100	91a	93a		84a	80a	74a	51a		65a	64a

Means in columns followed by a different letter are significantly different at $p < 0.05$.

The absence of a significant negative impact of seed placed CRP for these crops for rates up to 80 – 100 kg P_2O_5 ha^{-1}, implies much improved crop safety for controlled-release P fertilizer compared to

conventional P fertilizer. A reduced salt-effect/damage potential from a CRP product would be of benefit in potentially allowing higher rates to be safely placed and a greater of quantity of other nutrients to be seed-row placed along with phosphorus in single shoot systems. As noted before, the 20 kg K_2O ha^{-1} seed placed does have a detrimental effect for some crops like pea and canaryseed, and in combination with high rate of CRP, reducing germination starts to become apparent, albeit at much higher rates than for conventional MAP plus K_2O.

Table 8. Percentage of seeds planted that emerged over 2 weeks as affected by different rates of controlled released phosphorus (CRP) fertilizer with or without 20 kg K_2O ha^{-1} potash for bromegrass, mustard, yellow pea, and alfalfa.

Fert. rate	Bromegrass		Mustard			Yellow pea		Alfalfa		
	P only	With K	P only		With K	P only	With K	P only		With K
kg P_2O_5 ha^{-1}	2006	2006	2005	2006	2006	2005	2006	2005	2006	2006
0	69a	61a	72a	70a	64a	88a	75a	64a	72a	72a
10	66a	59ab		68a	68a		71a		71a	78a
20	69a	58ab	67a	70a	66a	91a	75a	60a	72a	79a
30	62a	54abc		73a	66a		68a		67a	74a
40	60a	56ab	62a	70a	64a	81a	71a	63a	67a	75a
60	66a	53abc	75a	71a	68a	63a	64a	51a	72a	72a
80	56a	46bc	65a	68a	64a	59a	68a	71a	71a	69a
100	58a	42c		66a	61a		68a		71a	69a

Means in columns followed by a different letter are significantly different at $p < 0.05$.

Table 9. Percentage of seeds planted that emerged over 2 weeks as affected by different rates of controlled released MAP (CRP) fertilizer with or without 20 kg K_2O ha^{-1} potash for oat, pinto bean, and chickpea.

Fert. rate	Oat		Pinto bean	Chickpea
	P only	With K	With K	With K
kg P_2O_5 ha^{-1}	2006	2006	2006	2006
0	92a	89a	89a	86a
10	92a	83a	89a	86a
20	89a	86a	89a	89a
30	89a	75a	86a	82a
40	89a	89a	86a	86a
60	89a	86a	89a	79a
80	86ab	83a	82a	82a
100	81b	81a	86a	82a

Means in columns followed by a different letter are significantly different at $p < 0.05$.

Effect of P Fertilizer on Plant Dry Matter Yield

Table 10. Dry matter yield (grams per 50 cm of seed row) measured 4 weeks after emergence as affected by 5 different rates of seed-placed conventional MAP fertilizer with or without 20 kg K_2O ha^{-1} potash for wheat, canola, and yellow pea.

Fert. rate	Wheat			Canola			Yellow pea	
	P only		With K	P only		With K	P only	With K
kg P_2O_5 ha^{-1}	2004	2005	2006	2004	2005	2006	2004	2006
0	0.87b	0.79e	0.72c	0.97c	0.86c	1.25c	0.67ab	0.99b
10	1.02b	1.09bc	0.77bc	1.21abc	1.04bc	1.64ab	0.71a	1.19a
20	1.06b	1.19ab	0.89ab	1.16bc	1.13ab	1.81a	0.44b	0.84bc
30	1.12ab	1.31a	0.88ab	1.49a	1.33a	1.80a	0.44b	0.67c
40	1.21a	1.31a	1.03a	1.38ba	0.90c	1.48b	0.44b	0.47c

Means in columns followed by a different letter are significantly different at $p < 0.05$.

Table 11. Dry matter yield (grams per 50 cm of seed row) measured 4 weeks as affected by 5 different rates of seed-placed MAP fertilizer with or without 20 kg K_2O ha^{-1} potash for flax, bromegrass, canary, mustard, alfalfa, pinto bean and chickpea.

Fert. rate	Flax		Bromegrass	Canary	Mustard	Alfalfa	Pinto bean	Chickpea
	P only	With K						
kg P_2O_5 ha^{-1}	2004	2006	P only in 2004					
0	0.18a	0.53a	0.08b	0.33a	0.84a	0.20c	1.19a	0.78a
10	0.17a	0.57a	0.24a	0.31a	0.73a	0.36a	1.18a	0.86a
20	0.19a	0.57a	0.18ab	0.39ab	0.92a	0.32ab	1.24a	0.65a
30	0.28b	0.73a	0.25a	0.39ab	0.67a	0.31abc	1.44a	0.57a
40	0.27b	0.47a	0.09b	0.44b	0.66a	0.23bc	1.34a	0.76a

Means in columns followed by a different letter are significantly different at $p < 0.05$.

Table 12. Dry matter yield (grams per 50 cm of seed row) measured 4 weeks as affected by 5 different rates of seed-placed CRP fertilizer with or without 20 kg K_2O ha^{-1} potash for wheat, canola, and yellow pea.

Fert. rate	Wheat		Canola		Yellow pea	Flax
	P only	With K	P only	With K	With K	With K
kg P_2O_5 ha^{-1}	2005	2006	2005	2006	2006	2006
0	0.79e	0.72bc	0.86b	1.25b	0.99a	0.53a
10	0.88de	0.66c	0.90ab	1.48b	0.98a	0.50a
20	0.99cd	0.72b	0.96ab	1.51b	0.95a	0.52a
30	1.13bc	0.87ab	1.13a	1.95a	1.05a	0.61a
40	1.21ab	0.92a	1.14a	1.80a	1.02a	0.63a

Means in columns followed by a different letter are significantly different at $p < 0.05$.

In the 2004 study, a good yield response in the first 4 weeks of growth to the seed-placed P was achieved in the crops up to the point where injury was observed in the mustard, bromegrass, alfalfa

and pea (Tables 10 and 11). In the case of bromegrass, dry matter yield at rate of 40 kg P_2O_5 ha^{-1} dropped back to a similar value to that with no P addition, and is explained as a result of injury to the stand (Table 4). A similar reason explains the trend of negative response to P in the treatments of mustard and yellow pea to the seed-placed P (Tables 10 and 11), as injury to the stand was observed in these crops at higher rate of P fertilizer (Tables 3, 4, 5 and 6). With the exception of chickpea, pinto bean, mustard, and pea, all crops responded significantly in early growth to seed-placed MAP with or without K, with responses in sensitive crops limited by reduced emergence and reduced plant density at high rates.

It is not possible to directly evaluate the effect of the added 20 kg K_2O ha^{-1} on yield versus without at the same rates of added P, as the trials were conducted in different years under slightly different conditions. However, the high levels of extractable available K in this soil would likely preclude any significant response to K fertilizer addition. The soil used in the experiment was quite deficient in available P according to extraction (18 lb/ac modified Kelowna extractable P 0-15 cm). Overall, 10 – 20 kg P_2O_5 ha^{-1} of added fertilizer P tended to be sufficient added P in this soil to maximize early dry matter yield for most crops in the growth chamber. A similar trend was observed in both 2005 and 2006 studies. Absolute values of yields are different among the years due to difference in experimental conditions in the chamber from year to year. Yield normally increased with increased rate of MAP up to the point when injury was observed, as in canola at rate of 40 kg P_2O_5 ha^{-1} (Table 3) with or without potash addition (2005 and 2006) and in yellow pea up to 10 kg P_2O_5 ha^{-1} .As no injury occurred when CRP was used, a significant increase in yield was observed in wheat and canola crops in both 2005 and 2006 studies with or without 20 kg K_2O ha^{-1} added together up to 40 kg P_2O_5 ha^{-1} (Table 12). However, no increase in crop yield was noted for yellow pea and flax although there was a trend for yield increase with flax (Table 12). Comparing yields of conventional MAP to CRP (Table 11 and Table 12), the biomass yields are similar, except at high rates with sensitive crops like flax and pea, where because the CRP does not reduce emergence and plant density, the CRP yields are higher. These results agree with findings by Pauly et al (2002)

who reported that conventional MAP sometimes resulted in slightly higher yields and P uptake than CRP in early stages of growth, but CRP performed better in later stages of growth. As the measurements made in this study included only the first 30 days of plant growth, the effect in later stages was not evaluated.

Effect of P Fertilizer Rate on Plant P Uptake

The addition of conventional MAP led to the expected increase in P uptake with or without potash addition until the point where crop injury occurred with some crops such as with pea (Tables 13 and 14). For most crops, P uptake was maximized around 20 – 30 kg P_2O_5 ha^{-1}, with exception of mustard, alfalfa and pinto bean with no significant effect of P fertilizer on uptake in 2004, although alfalfa showed a small yield response. The effect of adding K on P uptake cannot be evaluated because of different experimental conditions in the different years. For controlled release phosphorus (CRP) fertilizer, as with yield response to CRP addition, increase in P rates with or without K addition led to increase in P uptake (Table 15). No decrease in P uptake was noted in 2005 and 2006 growth chamber studies with or without K addition (Table 15) as crops were injury free up to the rate of 40 kg P_2O_5 ha^{-1}. With CRP, as for conventional MAP, crop P uptake was maximized around 30 kg P_2O_5 ha^{-1}. As with yield, there was little difference in early season P uptake between CRP and conventional MAP for the same crop and same rate of added P, suggesting that P availability from the two different sources is similar in this soil under these conditions. Evaluation in a wider range of soils under field conditions is needed to verify the effect of P form on availability.

Table 13. Crop P uptake (mg P uptake per 50 cm of seed row) measured 4 weeks as affected by 5 different rates of seed-placed MAP fertilizer with or without 20 kg K_2O ha^{-1} potash for wheat, canola, and yellow pea

Fert rate	Wheat			Canola			Yellow pea	
	P only		With K	P only		With K	P only	With K
kg P_2O_5 ha^{-1}	2004	2005	2006	2004	2005	2006	2004	2006
0	1.60c	2.89d	2.09a	0.59b	3.80e	5.17d	0.42a	3.45ab
10	2.65b	4.11c	2.44a	0.58b	5.85d	7.24c	0.91a	4.29a
20	3.05b	5.15b	3.03b	0.65b	7.05bc	9.23ab	0.88a	3.37ab
30	3.60a	6.53a	3.63a	1.00a	8.83a	9.50a	0.82ab	2.90bc
40	3.83a	6.38a	4.11a	0.98a	5.97cd	8.07bc	0.65a	2.24c

Means in columns followed by a different letter are significantly different at $p < 0.05$.

Table 14. Crop P uptake (mg P uptake per 50 cm of seed row) measured 4 weeks as affected by 5 different rates of seed-placed MAP fertilizer with or without 20 kg K_2O ha^{-1} potash for canary, mustard, alfalfa, pinto bean, chickpea, and flax.

Fert rate	Canary	Mustard	Alfalfa	Pinto bean	Chickpea	Flax
	---------- P only in 2004 ----------					With K
kg P_2O_5 ha^{-1}						2006
0	1.32c	2.01a	2.69a	4.85a	0.23c	2.07b
10	1.91b	2.06a	3.04a	3.63a	0.87a	2.21b
20	2.06b	1.44a	2.68a	3.32a	0.71ab	2.42ab
30	3.16a	1.41a	3.50a	3.19a	0.77ab	3.34a
40	2.97a	1.49a	3.72a	4.29a	0.34bc	2.95ab

Means in columns followed by a different letter are significantly different at $p < 0.05$.

Table 15. Crop P uptake (mg P uptake per 50 cm of seed row) measured 4 weeks as affected by 5 different rates of seed-placed CRP fertilizer with or without 20 kg K_2O ha^{-1} potash for wheat, canola, yellow pea, and flax.

Fert rate	Wheat		Canola		Yellow pea	Flax
	P only	With K	P only	With K	With K	With K
kg P_2O_5 ha^{-1}	2005	2006	2005	2006	2006	2006
0	2.89d	2.09d	3.80c	5.17c	3.45b	2.07c
10	3.83c	2.01d	5.18b	6.94b	2.76c	2.33c
20	4.61bc	2.56c	5.83b	8.27b	3.69b	2.48bc
30	6.51a	3.28b	7.68a	11.04a	4.02ab	2.87ab
40	7.23a	3.71a	7.78a	10.93a	4.45a	3.08a

Means in columns followed by a different letter are significantly different at $p < 0.05$.

Effect of K Fertilizer Rate on Emergence Counts

A separate trial was conducted to evaluate the effect of seed-placed K alone. Placement of K alone in the seed-row would not be a common practice in Saskatchewan, as K deficiency without P deficiency would be uncommon. Due to lower frequency of K deficiency compared to P, in most cases growers place P in the seed-row alone or P + K. For seed-placed K alone, there was no negative impact for wheat and oat up to 80 kg K_2O ha^{-1} (Tables 16 and 17) and for most crops no negative impact up to 60 kg K_2O ha^{-1}. Canary seed, brome, mustard and pea showed greater sensitivity, with reduction in germination above 30 – 40 kg K_2O ha^{-1}. Note that for this experiment the counting period for emergence was 20 days instead of 14 as in all previous experiments.

Table 16. Percentage of seeds planted that emerged* as affected by different rates of K fertilizer for wheat, oat, canary, bromegrass, canola, and mustard.

Fert. rate	Wheat	Oat	Canary	Bromegrass	Canola	Mustard
Kg K_2O ha^{-1}						
0	95a	78a	76ab	43a	98a	64a
10	86a	86a	80a	38ab	89ab	61ab
20	91a	81a	69ab	32ab	95a	66a
30	84a	83a	74ab	29ab	98a	55abc
40	96a	78a	69ab	33ab	95a	48bc
60	94a	78a	59bc	29bc	98a	45c
80	89a	75a	48c	13c	84b	48bc

For each crop, means in columns followed by a different letter are significantly different at $p < 0.05$.
*Refers to % of planted seeds that emerged over 20 days

Table 17. Percentage of seeds planted that emerged* as affected by different rates of K fertilizer for flax, pinto bean, alfalfa, chickpea, and yellow pea.

Fert. rate	Flax	Pinto bean	Alfalfa	Chickpea	Yellow pea
Kg K_2O ha^{-1}					
0	63a	86ab	63a	82ab	71a
10	57a	82ab	61a	82ab	68ab
20	58a	93a	64a	86a	64ab
30	60a	79ab	61a	75ab	61ab
40	57a	68b	57ab	71ab	64ab
60	56a	75ab	57ab	68b	54ab
80	47a	71ab	46b	50c	43b

For each crop, means in columns followed by a different letter are significantly different at $p < 0.05$.
*Refers to % of planted seeds that emerged over 20 days

CONCLUSION AND RECOMMENDATIONS

The majority of crops tested in the flats of soil in the laboratory showed no negative impact on seed germination and emergence with seed-placed conventional P fertilizer, with or without 20 kg K_2O ha^{-1} potash addition, at rates up to ~ 20 to 30 kg P_2O_5 ha^{-1}. Yellow pea, flax and mustard tended to be most sensitive to seed placed MAP. The controlled release phosphorus fertilizer (CRP) product greatly increased tolerance of crops to high rates of seed-placed P. Injury in the form of reduced germination and emergence was greatly reduced when controlled release P fertilizer was used, with

rates of 80 kg P_2O_5 ha^{-1} placed in the seed row resulting no significant injury for most crops. The CRP product would be advantageous when high rates of P fertilizer are desired to be applied in the seed-row with low-disturbance seeding equipment such as for seeding forages with a double disc press drill and trying to supply enough P fertilizer to last the life of the stand. Generally, a rate of 30 kg P_2O_5 ha^{-1} was sufficient to produce maximum yield and P uptake for both conventional MAP and CRP fertilizers. Large differences in P availability as revealed in crop yield and P uptake were not evident between the conventional P and controlled-released P forms. For most crops, the addition of 20 kg K_2O ha^{-1} starter K in the seed row to the P fertilizer did not have detrimental effects on germination and emergence, but some additional injury potential was evident with crops that appeared more sensitive to seed placed K such as canary seed and yellow pea.

The effect of CRP versus conventional MAP fertilizer on P availability should be evaluated in the growth chamber and field on a wider range of soil types with different chemistries and P fixation mechanisms. The impact of surface placement of CRP on availability and surface run-off loss potential would also be useful to study in future.

ACKNOWLEDGMENT

The financial support of the Agriculture Development Fund, Agrium Inc., and Potash and Phosphate Institute for this project is acknowledged at the end of presentations and papers given.

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Equipment

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Project Developed Materials

Papers

P. Qian, J.J. Schoenau, T. King and C. Fatteicher, 2006. The Impact of Conventional and Controlled Release Seed-row Placed Phosphorus Fertilizer on Emergence of Eleven Crops Under Controlled Environment Conditions. Canadian Society of Soil Science Annual Meeting Abstracts, May 14-17, Banff, Alberta, pp 106.

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